Amino acids in some seaweeds from Red Sea Coast – Egypt

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Abstract

Seaweeds form an important renewable source in the marine environment and have been known as a source of natural nutritive compounds such as free amino acids. For that purpose, this study aimed to investigate the amino acids contents of some brown (*Cystoseira trinodis*, *Saragassum muticum*, and *Turbinaria ornata*), red (*Laurencia papillosa*, *Jania rubens*, and *Coralina officinalis*), and green seaweeds (*Caulerpa racemose*, *Ulva lactuca*, and *Halimeda tuna*). Amino acids were analyzed using an LC 3000 eppendorf / Biotronik amino acid analyzer. Results revealed that the total amino acid content ranged from 11.84 ± 0.55 mg g^{-1} DW in *L. papillosa* to 33.43 ± 1.29 mg g^{-1} DW in *U. lactuca*. L-methionine and threonine were the major essential amino acids (EAAs) in Phaeophyta, and Chlorophyta species, respectively, whereas in Chlorophyta species, the major EAA was varied as L-lysine, L-leucine, and L-valine in *C. racemose*, *U. lactuca*, and *H. tuna*, respectively. In all the tested species, L-glutamic and L-aspartic acids constituted together a large part of the amino acid content forming 16.3 - 34.8% of total amino acids. Among the nine seaweeds, *U. lactuca* contained the highest amounts of EAAs (17.4 ± 0.73 mg g^{-1} DW). The amino acids compositions of seaweeds are highly influenced by seaweeds classes and species. The high content of EAAs in the tested species made them candidates for nutritional and pharmaceutical applications.

Keywords Amino acids; Phaeophyta; Rhodophyceae; Chlorophyceae; Red Sea; Seaweeds.

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1. Introduction

Seaweeds are multicellular marine algae that play important environmental, biological, and ecological roles in coastal environments (**Carneiro et al., 2014**). They are classified according to their anatomy, pigmentation, morphology, and chemical composition as brown (Phaeophyta), red (Rhodophyta), and green seaweeds (Chlorophyta) (**Dawczynski et al., 2007**). Seaweeds have many ecological roles as the food base for almost all aquatic life due to their high contents of nutrients regarding vitamins, fibers, free amino acids, polyunsaturated fatty acids, and minerals (**Ortiz et al., 2006**). The nutrient compositions of seaweeds are generally known to be highly influenced by species, habitats, maturity, geographical location, and environmental conditions (**Fleurence, 1999**).

Amino acids are precursors for the synthesis of secondary metabolites such as alkaloids, which provide chemical defense for seaweeds (**Croteau et al., 2000**). Generally, the amino acid profile is important for evaluating the nutritional value of seaweed proteins. The nutritional value of food protein is mainly determined by the type, amount and proportion of EAAs. Quantitative estimation of amino acids composition in different species of marine seaweeds reveals that there were considerable differences in amino acids between different algal species (**Qasim, 1991**).

About 150 seaweed species are favorably consumed, as human food in the coastal areas (**Kumari et al., 2010**). Approximately 25% of all food consumed in Japan consists of seaweed and prepared as sushi wrappings, jams, soups, vegetables and thus has become a main income source for the fishermen (**Anantharaman et al., 2010; Ortiz et al., 2006**). According to FAO statistics, South Korea, China, and Japan have the highest intake of seaweed, with a daily consumption of 46, 22, and 4 g per capita, respectively (**Robledo et al., 2013**).

Seaweeds of the present study are almost extensively available during the all months at Hurghada, Red sea coast of Egypt. Therefore in order to fully exploit the nutritional value of seaweeds, the present study aimed to investigate the amino acids content of some seaweeds to gain extensive information about their nutritional value.

2. Materials and Methods

2.1. Samples collection

Nine species of seaweeds; Phaeophyta (*Cystoseira trinodis*, *Saragassum muticum*, and *Turbinaria ornata*), Rhodophyta (*Laurencia papillosa*, *Jania rubens*, and *Coralina officinalis*), and Chlorophyta (*Caulerpa racemose*, *Ulva lactuca*, and *Halimeda tuna*) were collected during autumn season 2016. The seaweeds were collected by hand-picking from shores of Hurghada, Red sea coast of Egypt (Fig. 1) at the time of low-tide. Collection site is situated between 27° 13' N and 33° 45' E.

2.2. Preparation of seaweeds

Seaweeds were washed with seawater followed by distilled water to remove the salt and the extraneous foreign particles. Then the seaweeds were spread on blotting paper to remove excess water. The clean seaweeds were shade dried and then kept in an oven 60 °C for 4 hrs. The dried algal materials were ground to 2 mm or smaller particle size. The algal powders were then used for analyses.

Fig. 1. Map showing the collection site (Hurghada).

2.3. Investigation of amino acids profile

The algal samples were hydrolyzed according to the method of **Adebiyi et al. (2005)** before determination of amino acids. Amino acid analysis was carried out using an LC 3000 eppendorf / Biotronik amino acid analyzer with column type H 125 x in the National Institute of Oceanography and Fisheries, Alexandria, Egypt. Amino acids content was as expressed mg g^{-1} dry wt.

2.4. Statistical analysis

All determinations were carried out in triplicates and the results are expressed as a mean ± standard deviation. A significant difference between the means of the studied seaweeds parameters was determined using the statistical software Statistical Package for the Social Sciences (SPSS) Version 20.

3. Results and Discussion

The amino acid profiles of nine species of seaweeds revealed that these seaweeds contain 18 amino acids, namely L-lysine, L-methionine, tryptophan, threonine, L-phenylalanine, L-isoleucine, L-leucine, histidine, L-valine, L- aspartic acid, L- glutamic acid, arginine, glycine, alanine, serine, tyrosine, cysteine, and proline. The statistical analyses showed significant differences ($p<0.05$) in amino acid content between all algal species. The total amino acid content ranged from 11.84 ± 0.55 mg g^{-1} DW in *U. lactuca* to 33.43 ± 1.29 mg g^{-1} DW in *L. papillosa*. Variations in amino acids content may be proportional to its consumption by the seaweeds in reproduction and growth.

Table 1 showed that the seaweeds contained nine EAAs in different quantities, ranged from 42.3 ± 0.55% (in *T. ornata*) to 53.9 ± 0.62% (in *L. papillosa*) of the total amino acid content. This result was higher than that of the other seaweeds reported in earlier works; 37 - 42% in *U. lactuca* and *Gelidium amansii* (**Ochiai et al., 1987**) and 36.5 % in *Ulva rigida*, and *U. rotundata* (**Fleurence et al., 1995**). **Dawczynski et al. (2007)** reported that EAAs form more than 30% of the total amino acids in various seaweeds. The results also indicated that EAAS/ non-EAAs ratio was ranged from 0.73 in *T. ornata* to 1.17 in *L. papillosa*. It can be observed that L-methionine is the major EAA in Phaeophyta species and represents 32.4 - 37.9% of total EAAs. **Lourenço et al. (2002)** also reported high contents of methionine in brown seaweeds. Threonine is the major EAA in all studied Rhodophyta species, whereas in Chlorophyta species, the major EAA was varied as L-lysine, L-leucine, and L-valine in *C. racemose*, *U. lactuca*, and *H. tuna*, respectively. Further, it can be noted that tryptophan is much less quantity compared to all EAAs available in *S. muticum*, *L. papillosa*, *J. rubens*, and *C. racemose*, and completely absent in *C. trinodis*, *T. ornata*, *C. officinalis*, *U. lactuca*, and *H. tuna* (table 1).

The results also indicated variations in non -EAAs content among seaweeds species and classes. Seaweeds contained nine non-EAAs named as L- aspartic acid, L- glutamic acid, arginine, glycine, alanine, serine, tyrosine, cysteine, and proline. Non-EAAs ranged from 16.03 ± 0.56 mg g^{-1} DW in *U. lactuca*, and 5.46 ± 0.21 mg g^{-1} DW in *L. papillosa*. As shown in table 2, all the studied species showed a similar pattern in which L-glutamic and L-aspartic acids constituted together a large part of the amino acid content (16.3 - 34.8% of total amino acids). Similar results were also obtained in previous studies by **Wong (2000)**, **Kumar (2007)** and **Gressler (2010)**. In the present study, L-glutamic and L-aspartic acids represent 20.1 - 29.4% of the total amino acids in Phaeophyta species, 16.3 - 23.9% in Rhodophyta species, and 23.3 - 34.8% in Chlorophyta species. The level of these two amino acids in *U. lactuca* represent 34.8 % of the total amino acids, that was higher than those reported in *U. rigida* (26%) and *U. rotundata* (32%) by **Fleurence et al. (1995)**. According to **Mabeau et al. (1992)**, the high levels of aspartic and glutamic acids were responsible for the special flavor and taste of the seaweeds.

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Table 1. Essential amino acids profiles of some seaweeds.

Classes and species	L-lysine	L-methionine	Tryptophan	Threonine	L-Phenylalanine	L-isoleucine	L-leucine	Histidine	L-valine
Phaeophyta									
C. trinodis	0.79 ± 0.03	1.94 ± 0.08	ND	0.49 ± 0.03	0.68 ± 0.01	0.64 ± 0.01	0.82 ± 0.06	0.41 ± 0.03	0.21 ± 0.01
S. muticum	1.23 ± 0.06	3.83 ± 0.14	0.29 ± 0.03	1.04 ± 0.03	0.89 ± 0.06	0.77 ± 0.06	0.63 ± 0.01	0.69 ± 0.02	0.74 ± 0.01
T. ornata	0.52 ± 0.01	2.71 ± 0.14	ND	0.72 ± 0.06	1.06 ± 0.11	0.89 ± 0.09	1.44 ± 0.08	0.67 ± 0.06	0.27 ± 0.01
Rhodophyta									
L. papillosa	0.69 ± 0.01	0.36 ± 0.03	0.18 ± 0.02	1.16 ± 0.07	1.09 ± 0.03	0.56 ± 0.07	0.91 ± 0.07	0.89 ± 0.01	0.54 ± 0.03
J. rubens	0.89 ± 0.09	0.41 ± 0.01	0.92 ± 0.03	2.06 ± 0.12	0.62 ± 0.00	1.32 ± 0.03	0.97 ± 0.03	1.72 ± 0.08	1.15 ± 0.09
C. officinalis	1.15 ± 0.05	0.97 ± 0.04	ND	1.51 ± 0.03	1.22 ± 0.07	0.94 ± 0.03	1.43 ± 0.07	0.76 ± 0.01	0.89 ± 0.04
Chlorophyta									
C. racemose	1.74 ± 0.07	0.89 ± 0.03	0.59 ± 0.00	1.45 ± 0.07	1.13 ± 0.09	0.70 ± 0.03	1.66 ± 0.06	0.63 ± 0.01	0.82 ± 0.09
U. lactuca	2.81 ± 0.12	1.95 ± 0.08	ND	3.02 ± 0.21	0.81 ± 0.03	2.21 ± 0.08	4.39 ± 0.10	0.78 ± 0.03	1.43 ± 0.08
H. tuna	1.14 ± 0.10	0.73 ± 0.02	ND	1.08 ± 0.06	1.17 ± 0.10	1.52 ± 0.06	1.85 ± 0.09	0.34 ± 0.01	2.21 ± 0.09

EAAs are presented in mg g^{-1} DW. Values are means of three replicates ± standard deviations. ND: not detected

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Table 2. Non-essential amino acids profiles of some seaweeds.

Classes and species	L- Aspartic acid	L- Glutamic acid	Arginine	Glycine	Alanine	Serine	Tyrosine	Cysteine	Proline
Phaeophyta									
C. trinodis	1.73 ± 0.14	2.15 ± 0.14	1.27 ± 0.08	0.18 ± 0.01	0.17 ± 0.01	0.45 ± 0.01	0.59 ± 0.01	0.32 ± 0.01	0.36 ± 0.01
S. muticum	1.76 ± 0.08	2.19 ± 0.08	1.84 ± 0.14	0.63 ± 0.02	0.71 ± 0.03	0.78 ± 0.03	0.68 ± 0.03	0.35 ± 0.01	0.57 ± 0.02
T. ornata	2.32 ± 0.11	3.43 ± 0.14	1.91 ± 0.08	0.25 ± 0.01	0.29 ± 0.01	0.68 ± 0.03	1.18 ± 0.05	0.55 ± 0.01	0.68 ± 0.01
Rhodophyta									
L. papillosa	1.73 ± 0.06	1.10 ± 0.03	0.09 ± 0.01	0.02 ± 0.01	0.43 ± 0.01	ND	0.06 ± 0.01	ND	2.03 ± 0.08
J. rubens	2.09 ± 0.08	1.74 ± 0.08	0.95 ± 0.03	1.18 ± 0.08	1.73 ± 0.08	1.49 ± 0.06	0.53 ± 0.00	ND	1.63 ± 0.08
C. officinalis	2.26 ± 0.08	1.51 ± 0.14	0.32 ± 0.04	0.82 ± 0.03	1.43 ± 0.08	1.04 ± 0.03	0.47 ± 0.05	0.19 ± 0.01	1.16 ± 0.06
Chlorophyta									
C. racemose	1.61 ± 0.06	3.15 ± 0.14	0.74 ± 0.03	1.07 ± 0.08	1.12 ± 0.06	1.41 ± 0.06	0.46 ± 0.03	ND	1.25 ± 0.06
U. lactuca	5.44 ± 0.14	6.19 ± 0.21	0.24 ± 0.04	0.78 ± 0.02	1.17 ± 0.06	0.92 ± 0.03	0.46 ± 0.03	0.14 ± 0.01	0.69 ± 0.03
H. tuna	3.51 ± 0.14	2.83 ± 0.14	0.37 ± 0.04	1.15 ± 0.08	1.6 ± 0.13	0.97 ± 0.06	0.07 ± 0.01	ND	1.17 ± 0.02

Non-EAAs are presented in mg g^{-1} DW. Values are means of three replicates ± standard deviations. ND: not detected

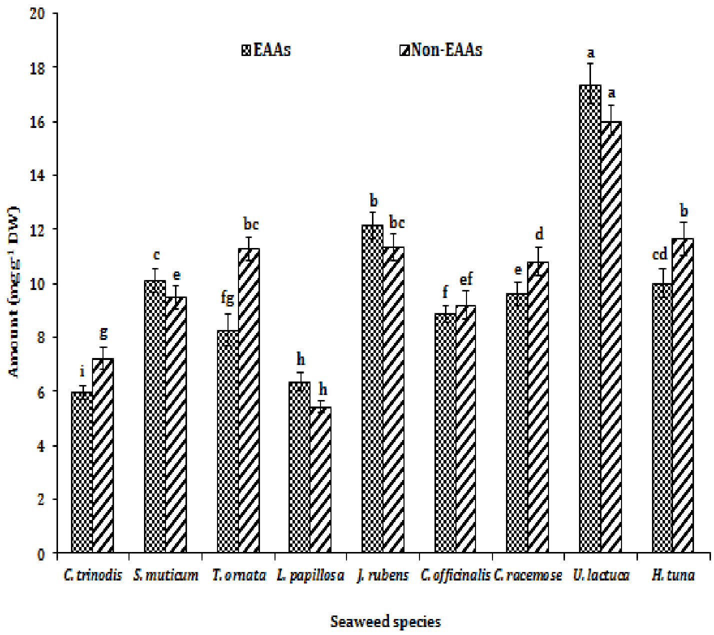

Fig. 2. Amount of EAAs and non-EAAs in the studied seaweeds

The total amino acid content in Phaeophyta species were ranged from 13.2 ± 0.68 mg g^{-1} DW in *C. trinodis* to 19.62 ± 0.86 mg g^{-1} DW in *S. muticum.* The ratio of EAAs to total amino acids were 0.45, 0.52, and 0.42 in *C. trinodis*, *S. muticum*, and *T. ornata*, respectively. **Ismail (2016)** reported lower ratio of EAAs to total amino acids in *Sargassum linifolium* (0.37). The results also indicated variations in EAAs/ non-EAAs ratio among the tested Phaeophyta species, 0.83 in *C. trinodis*, 1.06 in *S. muticum*, and 0.73 in *T. ornata*. All the tested Phaeophyta species were rich in L- glutamic acid, L-methionine, L- aspartic acid, and arginine. *C. trinodis* and *T. ornata* were poor in alanine, glycine, and L-valine, while *S. muticum* was poor in tryptophan, cysteine, and proline. No tryptophan was detected in *C. trinodis* and *T. ornata*. As shown in Fig. 2 among the three seaweeds, *S. muticum* contained higher amounts of EAAs (10.11 mg g^{-1} DW).

The total amino acid content in Rhodophyta species were ranged from 11.84 ± 0.55 mg g^{-1} DW in *L. papillosa* to 23.40 ± 0.97 mg g^{-1} DW in *J. rubens*. The ratios of EAAs to total amino acid were 0.54, 0.52, and 0.49, and that of EAAs/non-EAAs was 1.17, 1.07, and 0.96 in *L. papillosa*, *J. rubens*, and *C. officinalis* respectively. Cysteine and serine weren't detected in *L. papillosa*, whereas cysteine, and tryotophan weren't detected in *J. rubens* and *C. officinalis*, respectively. As shown in Fig. 2 among the Rhodophyta seaweeds, *J. rubens* contained higher amounts of EAAs (12.15 ± 0.48 mg g^{-1} DW), especially aromatic amino acids, threonine (2.06 ± 0.12 mg g^{-1} DW) and tryptophan (0.92 ± 0.03 mg g^{-1} DW).

The total amino acid content in Chlorophyta species were ranged from 20.42 ± 0.97 mg g^{-1} DW in *C. racemose* to 33.43 ± 1.29 mg g^{-1} DW in *U. lactuca*. The ratio of EAAs to total amino acids were 0.47, 0.52, and 0.46 in *C. racemose*, *U. lactuca*, and *H. tuna*, respectively. Tryptophan wasn't detected neither in *U. lactuca*, nor *H. tuna*, whereas cysteine wasn't detected in *C. racemose* and *H. tuna*. In other studies, tryptophan wasn't detected in different species of *Ulva* (**Lourenço et al., 2002; Ortiz et al., 2006**). Among the nine seaweeds, *U. lactuca* contained higher amounts of EAAs (17.4 ± 0.73 mg g^{-1} DW) as shown in Fig. 2. Moreover, *U. lactuca* was rich in sulphur containing amino acids, leucine (4.39 ± 0.10 mg g^{-1} DW) and lysine (2.81 ± 0.12 mg g^{-1} DW).

Therefore, the considerable quantities of all EAAs in the studied seaweeds implying good proteins quality and indicates that the seaweed proteins are nutritionally more than the terrestrial plant proteins and could be utilized as valuable nutritional ingredient for food.

4. Conclusions

It can be concluded that the nutritional compositions of seaweeds are highly influenced by seaweeds classes and species. All nine species of seaweeds examined in this study represent natural resources with potential economic value for use in human and animal nutrition due to their high content of essential amino acids. Further studies should be conducted with more species in order to determine their biochemical contents.

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